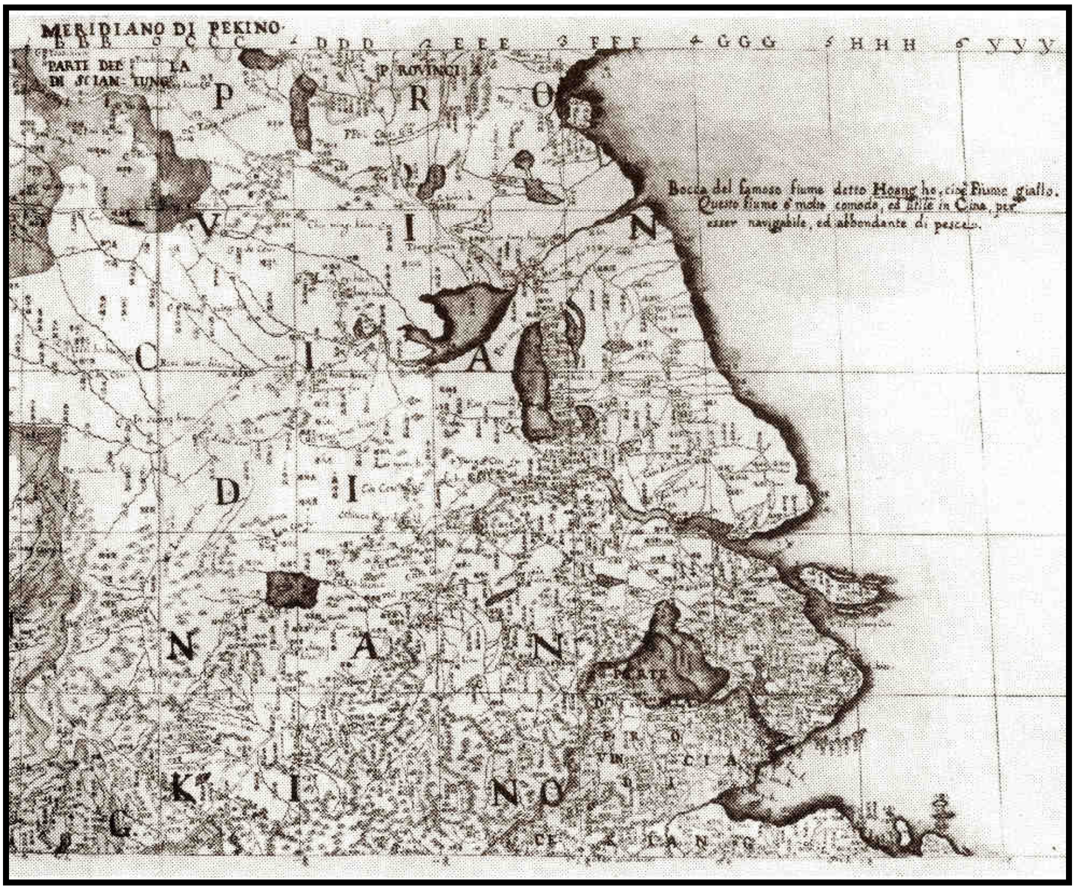
CHINA-ITALY BILATERAL SYMPOSIUM ON THE COASTAL ZONE: EVOLUTION AND SAFEGUARD

4 - 8 November 2007 Bologna, ITALY



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LAND SUBSIDENCE MONITORING TECHNIQUES A NEW STRATEGY ADOPTED IN THE VENETIAN AREA, ITALY

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Abstract

Among recent research topics dealing with land subsidence in the Venice region, great attention has been given to monitoring techniques. Recently, SAR-based analyses have been used to complement the ground-based methods, and an integrated monitoring system based on levelling, GPS, and InSAR techniques (SIMS), able to optimize the areally distributed information and to provided synoptic maps of ground surface displacements with high accuracy and reliability for both small areas and al regional scale was developed.

Keywords: *Veneto Region (Italy), subsidence, monitoring techniques, data integration (SIMS)*

INTRODUCTION

Until 1993, surveys in the Venice region were based on a few leveling lines starting inland and running along the coast and the lagoon edges with only the city of Venice controlled by a fine grid of benchmarks. In recent years, this leveling network has been updated to cover all the southern and the northern sector out of the lagoon. The new network was then adopted for differential GPS measurements, the differential SAR interferometry and the interferometric point target analysis (IPTA). To overcome the limits that characterize each single method and to enlarge the knowledge on regional land subsidence, an integrated monitoring method has been designed. We combine five earth observation techniques, i.e. spirit leveling, Continuous Global Positioning System (CGPS), Differential GPS (DGPS), Interferometric Synthetic Aperture Radar (InSAR), and Interferometric Point Target Analysis (IPTA), and homogenized and integrated their results in both the time and space domains. The application of this Subsidence Integrated Monitoring System (SIMS) provides a new complete and dependable picture of the vertical displacements in the Veneto Region never available before.

LAND SUBSIDENCE MONITORING. TECHNIQUES AND REGIONAL NETWORKS

Ground-surface elevation in the Venice Region has been measured by leveling with sufficient accuracy and reliability since the end of 1800. During the last decades Global Positioning System (GPS) techniques has been also adopted. More recently, significant progress in measuring ground displacements was achieved using Synthetic Aperture Radar-based techniques (SAR).

Leveling

Starting from 2000 a program has been carried out to homogenize ad to update the regional leveling nets . The existing coarse network has been refined especially in the southern and the northern parts of the coastal plain. Presently, the overall leveling network is about 1200 km long, consisting of about 1300 benchmarks, usually about 1 km apart, with about 50 closed polygons few tens of kilometers long (Figure 1). The original net, connected before 2000 only to the stable area of Treviso (Alpine foothills), is linked today also to the Monte Venda in the stable Euganean Hills.

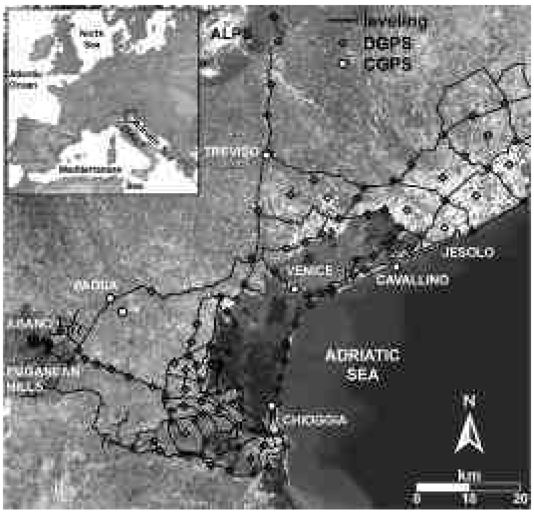

Figure 1 – networks of levelings, DGPS and CGPS presently available in the eastern Veneto Region (after Carbognin et al., 2005). The completion of regional net with new lines over the central areas is in course.

GPS

Two GPS techniques are presently used: the continuous (CGPS) and the differential one (DGPS). CGPS is based on a restricted number of stations providing long time series that can be used to monitor the displacement rates of few reference benchmarks in the vertical as well as the two horizontal directions; DGPS is generally applied on a coarse benchmark net and is faster and cheaper than leveling but less accurate. Its application appears particularly interesting to connect the subsiding areas to stable reference points and to perform expeditious surveys. The DGPS network is nowadays composed of one hundred and fifty suitable selected benchmarks of the leveling net, and five CGPS stations exist in the study area (Figure 1). The DGPS network has been connected to the five continuous GPS stations and the surveys carried out in static mode in 2000 and 2003 have confirmed the subsidence trends shown by leveling

InSAR

Interferometric Synthetic Aperture Radar (InSAR) has been introduced as a tool to measure land subsidence at the beginning of 1990. InSAR allows mapping land movements at high spatial resolution and sub-cm accuracy (Strozzi et al., 2001; Tosi et al., 2002). The InSAR investigation in the Venice Region has pointed out many locations with a coherent signal (Figure 2a) because of the high urbanization in this area (Strozzi et al., 2003).

IPTA

In order to overcome the main InSAR limitation, i.e. the incomplete spatial coverage limited to urban areas, new techniques to interpret the interferometric phase of stable reflectors (IPTA) have recently been developed on long time series of SAR images (Werner at al., 2003). Interferometric Point Target Analysis (IPTA) is particularly effective to monitor land displacements also for isolated, natural and/or artificial, man-made structures (Wegmüller et al., 2003; Teatini et al., 2007). More than 120,000 point targets (PT) with valuable subsidence information have been detected in the Venice Region, and they are scattered over cities, suburban areas, and isolated farm structures in rural areas (Figure 2b).

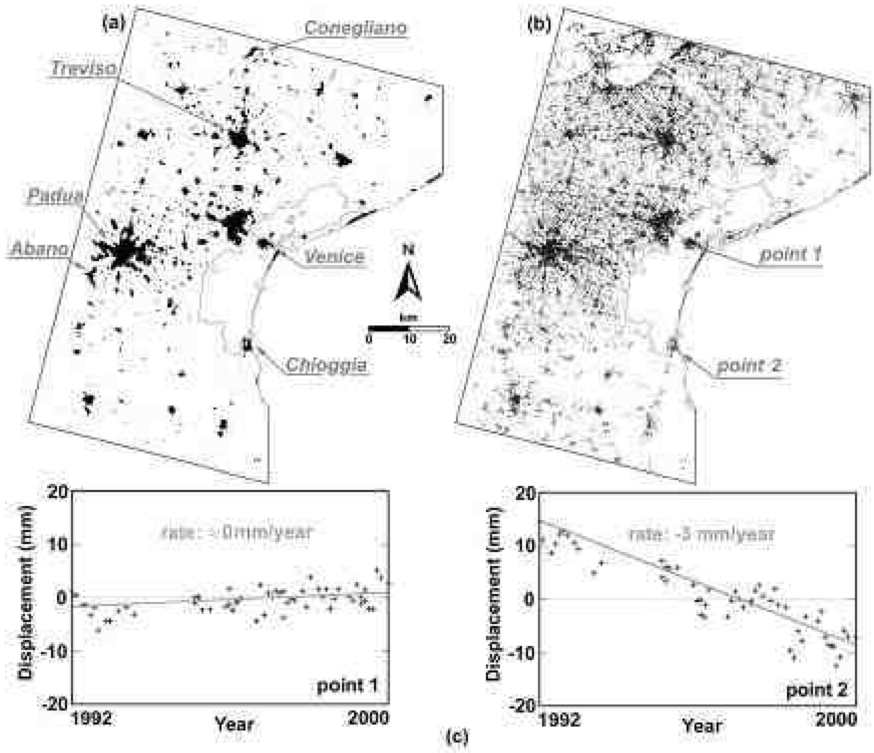

Figure 2. (a) InSAR and (b) IPTA networks in the eastern Veneto Region over the time period 1992-2000. Logs of subsidence for points 1 and 2 are shown in (c) (after Teatini et al., 2005)

SUBSIDENCE INTEGRATED MONITORING SYSTEM (SIMS)

To overcome the main limitations characterizing each of the five techniques briefly described, new monitoring system based on their integration (SIMS) has been developed to draw a comprehensive subsidence picture at regional scale (100×100 km area); the steps to implement SIMS are reported in figure 3.

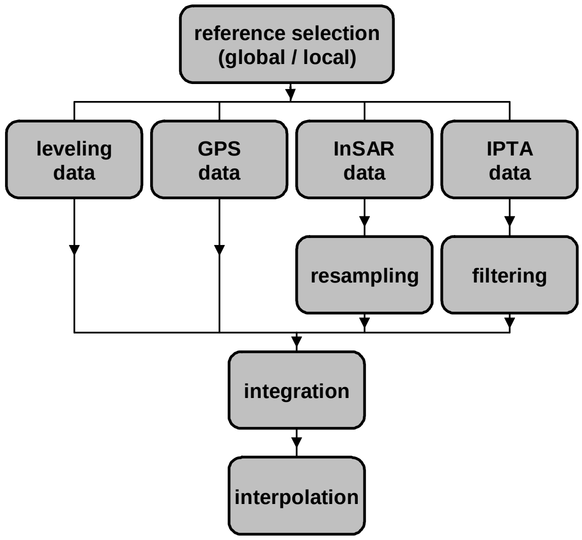

Figure 3 – Flow chart of the integration process to map regional land displacements (after Carbognin et al., 2005).

RESULTS

Using the SIMS with the available data above mentioned, a regional pattern of ground vertical displacements has been drawn for the Veneto Region, i.e. including all components (Fig. 4).

Figure 4 shows that the central part of the Veneto Region, including the major cities of Venice, Padua, and Treviso is generally stable, even in presence of scattered local bowls of subsidence up to 2-3 mm/y. Uplifts ranging from 0.5 to 1.5 mm/year have been measured in two different large areas located, respectively, north of Treviso and south of Padua, whereas higher values are restricted to the eastern sector of the Euganean Hills. Various processes, both natural and man-induced, are responsible for the measured ground vertical movements and give different contributions to the displacement rates (see the paper on land subsidence by the same authors in this volume).

CONCLUSIVE REMARKS

A new strategy to control wide-area vertical land displacements (SIMS) is implemented. Based on the integration of the conventional monitoring methods, SIMS allows optimizing the areally distributed remote-sensed information with the site-specific records measured by ground-based systems. The SIMS is applied in the eastern Veneto Region, over the last decade; it has enhanced the knowledge on land subsidence, allowing to map ground vertical displacements with good accuracy and with spatial coverage never available in the past.

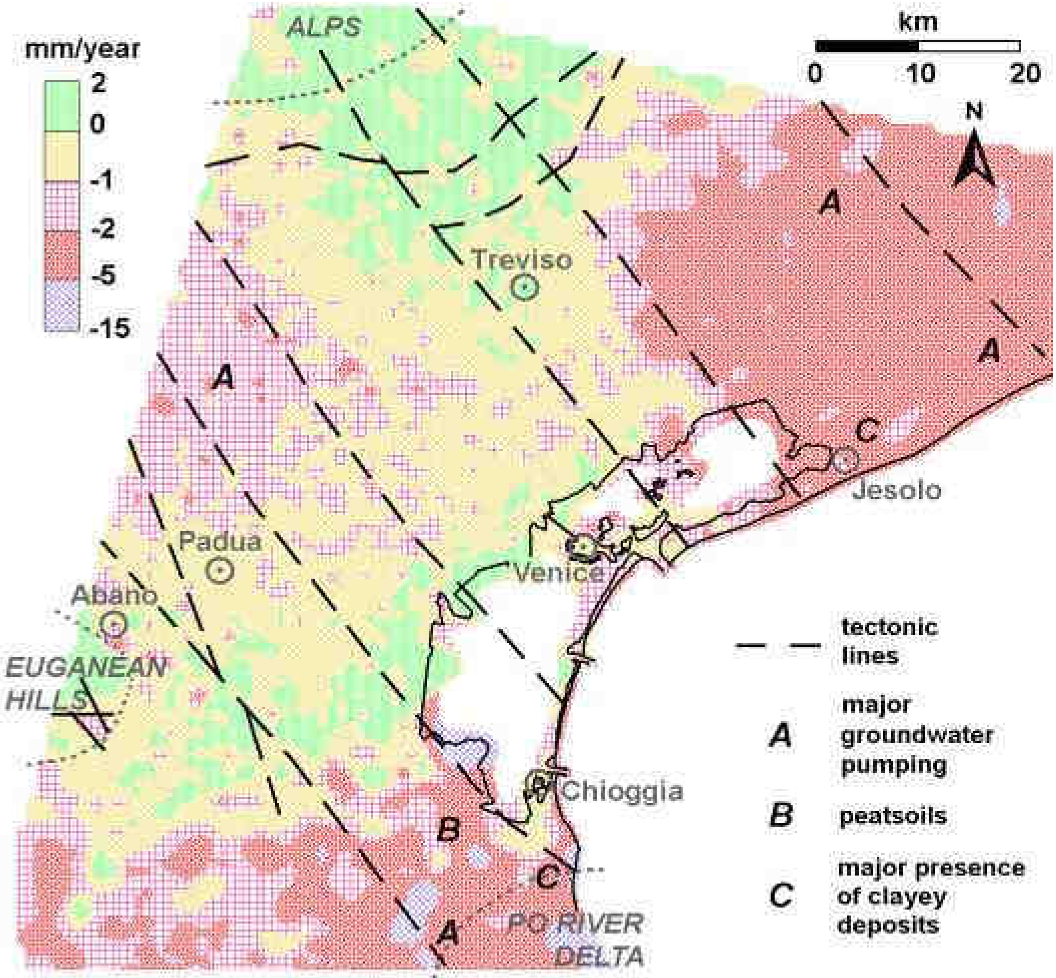

Figure 4 - Map of the displacement rates (mm/year) in the Venice region obtained by the SIMS over the decade 1992– 2002 (after Teatini et al., 2005).
Causes of land subsidence (*refer to paper by same authors in this volume)* are also reported.

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